Supplier Handbook:
Unidirectional (UD) Tape for the use in AFP laser-supported tape winding and placement (LATW/LATP) and production of continuous fiber reinforced thermoplastic (CFR TP) components

1. Introduction:

Alformet GmbH produces continuous-fiber reinforced thermoplastic tubes and profiles using the AFP process of laser-assisted tape winding, processing unidirectionally (UD) reinforced prepreg material commonly known as UD tapes. These UD tapes are sourced from Alformet through third-party suppliers whose business is either partially or entirely dedicated to their production. Alformet's operations are divided into two main business functions:

- **Standard Production**: This involves the manufacture of defined and validated product families according to specified requirements in series production using dedicated tooling, typically under long-term contracts. It also includes Alformet's web shop, the 'Online Tube Designer.' In this function, the chosen tape materials are fully qualified, and their performance is known under established processing parameters. Alformet guarantees the quality of the production, and consequently the laminate or product, by providing a production certificate.

- **Prototype Production**: This encompasses the iterative trial production of:
  (i) an unfamiliar design for a new or existing customer,
  (ii) an unknown tape material for either Alformet or the customer,
  (iii) winding on non-standard or untested tooling, or
  (iv) winding under unknown processing conditions.
  The quality of the process and product cannot be guaranteed by Alformet until these unknown factors are properly qualified.

This document serves as a set of general requirements and guidelines for delivering material to Alformet. It should complement, and not be superseded by, any UD tape supplier specification or project-specific material specification.

2. Qualification Levels of the UD Tape

Alformet distinguishes the following three levels of maturity to determine in which setting the material is qualified for use:

Trial Level	a. A tape that is unknown to Alformet due to: (i) a new grade development from a given supplier, (ii) a fiber-matrix combination with which Alformet has no prior processing experience, (iii) a new dimensional or physical configuration, such as fiber volume content (FVC) or thickness, or (iv) a non-qualified product from the tape supplier. b. A tape lacking the necessary certification as outlined in Section 8, *Documentation*. c. A Trial Level tape will not be used for customer production unless explicitly requested by the customer. d. Alformet does not assume any responsibility for failed productions using Trial Level tapes.
R&D Level	a. Alformet has performed basic processing tests, including hoop winding, cross winding, and angle winding (e.g., add-on-the-fly and cut-on-the-fly techniques). b. An R&D Level tape is one with which Alformet has basic experience and can, in good conscience, offer for use in customer projects. c. The supplier either: (i) has not qualified the tape, (ii) does not provide batch numbers or batch-specific certificates, or (iii) has irregular production practices. d. Alformet does not guarantee the performance of products made using R&D Level tapes.
Series Level	a. Alformet has achieved repeatable and reliable results through a process flow study across various diameters, winding angles, and processing conditions. b. Our partner institute has conducted a parameterization study and/or a characterization study. c. Products made from the tape have been validated by an end customer under specific processing conditions. d. A tape produced by the supplier that is: (i) qualified, (ii) certified, (iii) regularly manufactured, and (iv) appropriately labelled with batch numbers, with batch-specific certificates provided for each delivery. e. Alformet will guarantee products made using *Series Level* tape, provided the requirements of this document and specification are upheld by the supplier.

3. Qualification Levels of Suppliers

Alformet considers it's suppliers of UD-tapes to be of one of the following categories:

Qualified Supplier	Supplier has supplied either *R&D Level* or *Series Level* tapes and is set-up as a supplier in our system
Standard Supplier	Supplier regularly delivers at least one tape product for *standard production*.
Blocked Supplier	Supplier has either (i.) repeating quality issues in the delivery of a standard materials, (ii.) has refused to fill out an 8D report after the submission of a quality claim, or (iii.) does not uphold basic values of cooperation and partnership.

4. Delivery Format

For each of the following aspects are the following requirements to be observed:

Type of spooling	Required are pancake spooling, either on either Häfner BSH series spool or cardboard spools
Inner diameter of spooling	Häfner BSH standard. Cardboard core 3" or 6" inner diameter
Outer diameter of spooling	Standard maximum 630 mm. Maximum for vessel winding 1000 mm (Only Häfner BSH).
Spooling quality	A spool should be tightly wound enough that (i.) tape tension of 50 N doesn't cause slipping in the spool, (ii.) the spool doesn't fall apart during handling and (iii.) the winding is done evenly i.e. the side of spool is smooth.
Spool ends	The end of the spools should be arrived fixed with an adhesive that both does not fall apart during handling, but does not leave any residue when removed
Labeling	Suggestion for *R&D Level* tapes and requirement for *Series Level* tapes, each spool must be clearly, securely and uniquely labeled with the article description, batch and/or mother spool number, spool/cut number, and the length.
Spool length	Unless otherwise agreed upon, the minimum spool length is 200 m for *R&D Level* tapes and 500 m for *Series Level* tapes
Markings in the length	Unless otherwise agreed upon, there shall be no markings of any type, including but not limited to stickers and marking, along the length of the spool
Packaging	Polymers with a high moisture absorption rate (>3%) should be provided in appropriate packaging for storage (see 8. *Documentation*).

Alformet has a simple respooling machine available for necessary cases. Respooling is required if one or more of the following conditions are met:

i. The spool does not meet the dimensional requirements for mounting.
ii. The spool does not meet the type requirements, such as traverse spooling.
iii. The inner diameter of the spool is deformed or damaged.
iv. The material and cardboard core are not of the same width (with a maximum allowable difference of 1 mm).
v. The Häfner BSH spool flanges are damaged.

vi. The spool's stability is compromised due to poor spooling quality.

As a standard rule, if a significant length of material needs to be respooled for any of the above reasons, the manual effort and/or the cost of empty spools will be charged to the supplier. If the damage is fault of a third party (i.e. freight forwarder or slitter), Alformet and the supplier will come to an amicable agreement.

5. Process Specific Geometric Requirements

Point measurements of width, thickness or other geometrical effects are done representatively over one meter with five equidistant measurements. The width is done with a caliper and the thickness is done with a micrometer on each side (total ten measurements).

I. Tape Width and Tolerances:

At Alformet's facilities, the maximum width of material used for processing is 27 mm on most machines and up to 55 mm on others. The standard widths for processing are 12 mm, ½", 20 mm, 25 mm, 1", or 2". Other widths, ranging from 6 mm to 27 mm or up to 55 mm, are typically processable upon consultation.

The most critical aspect of the material for processing is the width tolerances. We aim to achieve a perfect edge-to-edge placement for a continuous seem between each tape track in every layer, as significant gaps or overlaps can affect both process stability and the quality of the final part. The material flow in the process varies from a few tenths of a millimeter to almost two millimeters, depending on the polymer, fiber volume content (FVC), thickness, width, and processing conditions. As a result, it is not feasible to specify a generalized tolerance for the material. Our process can be optimally programmed to ensure that the weld between tapes flows shut if the following criteria are met:

a. The nominal width value lies in the center of the tolerance range.
b. There are no extreme local variations in the width.
c. The specified tolerances are consistent across multiple batches.
d. The target difference between the minimum and maximum width (delta) is 0.2 mm, but not more than 0.4 mm.

II. Tape Thickness and Tolerances:

Most UD tapes have a thickness between 0.1 mm and 0.3 mm, and in these cases, they can be processed without any issues. Specialty materials may have a thickness of up to 2 mm on standard machines or a maximum of 3 mm after consultation. Thin ply materials (<0.1 mm) can be processed under certain conditions. A target tolerance for thickness should be ±5% of the nominal value, with a maximum allowance of ±10%.

For both process stability and successful production, it is crucial to maintain consistent thickness across the width of the tape. The target difference in thickness across the width should be <0.02 mm, with a maximum allowance of 0.04 mm.

III. Other Geometric Characteristics

The following material characteristics may also influence the laser-assisted tape winding process and should be avoided:

Effect	**Target Value**	**Limit Value**
Bending of tape (out of plane)	Radius >500 mm	Radius >250
Curvature of tape (in-plane)	Amplitude < ±0.1 mm or Wave length >3m	Amplitude < ±0.2 mm or Wave length >3m
Torsion of tapes in free state	<5° over 100 mm	<10° over 100 mm
Waviness of tapes in free state	< ±5° auf 1 m	< ±10° auf 1 m
Detachable dry fibers	0 g	< 0.1 g/kg
Cracks or kinks along the length	0	100 mm per crack/kink

In additional, the following unquantifiable requirements are also expected:

a. Dry fibers may not influence the tape guidance
b. Dry fibers may not influence the laser controller
c. Tapes must have a clean and flat edge
d. The tape edges must not be damaged during transportation or the slitting process
e. Local tape splits not allowed
f. Deflection radii (deflection rollers) with a diameter of 50 mm must be possible without splitting the tape
g. Spliced spools are not allowed, unless previously agreed upon
h. Marking of splices or defective areas are not allowed, unless previously agreed upon
i. Fibers inside the tape may not be broken

6. Process Specific Thermal Requirements

To ensure proper processing in the laser-assisted winding process, as well as in potential secondary processes where thermal treatment is necessary, the following thermal aspects are required:

Effect	**Limit Value**
Diode laser absorption color	Black
Homogenous laser absorption (Coefficient of Emissivity	For 1000 nm wavelength > 0.7 and maximum variance of ±0.1
Homogenous heating with IR-elements	Local temperature fluctuations <±10% (maximum <±20%) of the target temperature (over the tape width and over time)

The following non-quantifiable thermal requirements are expected of the tape:

a. The surface roughness may not negatively influence the laser controller
b. No polymer specific signs of degradation are allowed, i.e. the polymer must be in good thermal condition.

7. Product Specific Requirements

The following requirements are not necessary for a stable production, rather they do not influence the process quality. However, they are generally important for the end-product performance:

Effect	**Target Value**	**Limit Value**
Tolerance Fiber Volume Content (FVC)	±1%	±3%
Fiber-Matrix distribution	-	Per 1 mm tape width <±10%
Surface matrix content	FVC of the top or bottom 10% of the tape thickness < as average FVC of the tape	FVC of the top or bottom 10% of the tape thickness < as average FVC of the tape +5%
Porosity	<1%	<3%
Contamination of foreign materials	-	0

8. Documentation

First and foremost: No tape may be processed without a valid Material and Safety Data Sheet (MSDS). At a minimum, the MSDS must cover the individual components, i.e., the fiber and the matrix. This document must detail the effects of burning the specified materials and the required environmental or storage conditions. If the material cannot be delivered in suitable packaging, Alformet has limited capacity to dry the material before production.

The following basic/nominal information about the tape configuration must be known before any production: fiber type, matrix type, fiber volume content (FVC), tape width, and tape thickness. A valid Performance Data Sheet, which includes the physical properties of the material, is a requirement for *Series Level* tapes and a recommendation for *R&D Level* tapes. This sheet should contain, but is not limited to: tape configuration, aerial weight, density, tensile properties, and stiffness properties.

For *Series Level* tapes, batch-specific documentation is required with each delivery. This documentation must be assignable to specific batches and/or spools and should provide the necessary information to verify that the material is consistent with previous batches. This includes, but is not limited to: aerial weight, linear weight, actual width, actual thickness, and total spool weight. Most importantly, the spool length of each spool must always be provided with a positive tolerance; under no circumstances should the spools be shorter than the specified length. Finally, any spool defects must be described, and their locations clearly noted.

9. Quality Deviation and Claims

Quality deviations are not always precisely measurable. This document aims to list all potential failure modes in a way that can be discussed unambiguously. If a tape disrupts the process in a manner that cannot be countered through parameter adjustments or programming, the tape material supplier will be contacted and is expected to resolve the issue in good faith.

If Series Level tapes are found to violate any batch-specific measurements, project-specific measurements, or any hard limits set forth in this document, an official quality claim will be submitted, with the expectation of reimbursement for the material. For significant deviations that result in the loss of high-value products or require extensive effort from Alformet's employees, an 8D report will be submitted to the supplier. Any supplier who fails to return an 8D report will be internally blocked from further material supply.